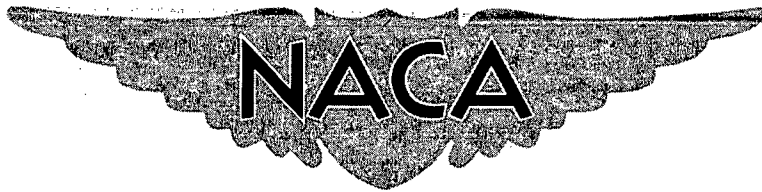NACA RM L55E03

RESEARCH MEMORANDUM

STATISTICAL MEASUREMENTS OF LANDING-CONTACT CONDITIONS

OF A HEAVY BOMBER

By Norman S. Silsby and Eziaslav N. Harrin

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
June 27, 1955

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

STATISTICAL MEASUREMENTS OF LANDING-CONTACT CONDITIONS

OF A HEAVY BOMBER

By Norman S. Silsby and Eziaslav N. Harrin

SUMMARY

Statistical measurements of landing-contact conditions have been
obtained for 144 landings of a heavy bomber airplane during routine
daytime operations at Carswell Air Force Base, Fort Worth, Texas. From
these measurements obtained by a special photographic method, sinking
speeds, bank angles, rolling velocities, and horizontal speeds at the
instant before contact have been evaluated and a limited statistical
analysis of the results has been made.

The analysis indicates that a sinking speed of about 7 feet per
second, a bank angle of about $4\frac{1}{2}^{\circ}$, a rolling velocity of about 3° per
second in the direction of the first wheel to touch or an airspeed at
contact of about 50 percent above the stall will be equaled or exceeded
once on the average in 1,000 landings.

INTRODUCTION

In order to aid in the development of more rational landing-loads
design requirements and procedures, the National Advisory Committee for
Aeronautics has, for the past two years, been conducting a project to
obtain statistical measurements of landing-contact conditions for var-
ious types of airplanes during routine daytime operations. Results for
478 landings of present-day transport airplanes are reported in
reference 1.

As a continuation of the project to obtain similar results for
other types of airplanes, including larger and heavier aircraft, rec-
ords have been obtained for 144 landings of a heavy bomber airplane
during routine operational landings at Carswell Air Force Base, Fort
Worth, Texas, during May and June 1954. Sinking speeds, horizontal
speeds, bank angles, and rolling velocities have been evaluated from
the records and a limited statistical analysis of the results has been
made.

APPARATUS AND METHOD

The measurements were made from 35-millimeter photographic records of the landings obtained according to a method described in reference 2. The equipment consists essentially of a constant-speed 35-millimeter motion-picture camera fitted with a telephoto lens of 40-inch focal length supported on a vertical shaft which provides for tracking the airplane only in azimuth. The 40-inch-focal-length lens permits setting up the camera at about 1,000 feet from the runway so that it offers no obstruction to aircraft on the airport proper. Photographs of 144 landings of the bomber were suitable for evaluation. General specification data for the airplane are given in table I. Further details of the method used to obtain the data and details of the reduction of the data with formulas used to obtain the landing-contact conditions of sinking speed, horizontal speed, bank angle, and rolling velocity can be obtained from references 1 and 2. Because of the appreciable slope of the runway, the sinking speed as evaluated by the method of reference 1 was corrected in accordance with the relation

$$\Delta V_V = V_H \frac{\alpha}{57.3}$$

where

ΔV_V increment of sinking speed, ft/sec

V_H horizontal velocity of airplane, ft/sec

α slope of runway, deg (positive with height of runway increasing in direction of landing aircraft)

With this correction the sinking speeds are given as the velocity normal to the runway rather than as the actual vertical velocity. For landings at the north end of the main runway (both runways run north and south) where the runway slope was the greatest, the sinking-speed correction was of the order of 0.7 foot per second for a horizontal velocity of about 160 feet per second.

ACCURACY

The accuracy in terms of probable error in the quantities determined as a result of errors in film reading and the error introduced by neglecting the vertical acceleration is as follows:

Sinking speed, ft/sec . . . . $\pm$0.1
Rolling velocity, deg/sec . . . . $\pm$1/4
Bank angle, deg . . . . $\pm$0.1
Horizontal velocity, ft/sec . . . . $\pm$1.5

For a more detailed account of sources of error and accuracy of the results, especially with regard to sinking speed, see reference 2.

Presentation of Results

The values of sinking speed, forward speed, bank angle, and rolling velocity, and other pertinent data are listed in table II for each of the 144 landings. The landings were being made during the normal operation of two different types of missions. One type consisted of single landings made by airplanes returning from extended (10 hours or more) missions, and the other type consisted of flights in which a series of 4 to 10 practice landings were made by one airplane over a several hour period on the same day. These two types of landings suggest a logical separation into two separate groups for statistical analysis in order to determine a possible difference in the landing-contact conditions due to pilot fatigue after long missions. However, because of the small number of landings in each group (82 practice landings and 62 landings terminating extended missions) it was believed to be impractical to isolate this effect. For the same reason it was believed impractical to isolate the effect of the gusty-wind condition, a factor which was found to have a significant effect on sinking speed, bank angle, and rolling velocity for the 478 transport airplane landings reported in reference 1. Therefore, the 144 landings of the bomber are considered and analyzed as one category. The results are presented in terms of frequency distribution (fig. 1) and probability curves (fig. 2). The class intervals used in the various frequency distributions were 0.5 foot per second for vertical velocity, 0.5° for bank angle, 0.5° per second for rolling velocity, and 5 percent above stall for airspeed at contact.

Probability data were arbitrarily faired by the Pearson type III probability curves determined in the manner described in reference 3. Values of the statistical parameters (mean value, standard deviation σ, and coefficient of skewness α_3) for sinking speed, bank angle, rolling velocity, and airspeed at contact, which were used in the determination of the probability curves, are listed in table III for the various conditions and groups considered. These curves (fig. 2), which fit the data reasonably well, provide a systematic fairing of the data, permit some extrapolation, and give an indication of the magnitude of the various quantities likely to be attained in a greater number of landings than were actually observed. It should be noted that values of the

landing-contact conditions for the extended portions of the probability curves are probably nonconservative because of the possibility of emergency or other nonroutine landings. The data points shown on the probability curves represent cumulative frequencies for the same class intervals that exist on the related frequency-distribution plots.

Most of the values of sinking speed presented in this paper are for the airplane center of gravity and were determined by taking the average of the sinking speeds for the two main-gear wheels at the time of the first wheel to contact. However, in the photographs of some landings only the first wheel to contact could be seen during the time interval immediately prior to contact for which the data were obtained; hence, only the sinking speed for this wheel was available. For such cases the sinking speeds were included with the rest of the data inasmuch as the results of reference 1 on transports indicated that there was no significant statistical difference between the sinking speed of the center of gravity and the first wheel to contact. Results for bank angle and rolling velocity were limited to those landings in which both wheel images were visible on the film records (86 of the present 144 landings). Both wheels were not visible in more landings because of the rather rapid rate at which the oblique spread of the wheels occurs (for camera angles away from the perpendicular to the runway) because of the large 45-foot gear tread of the heavy bomber.

When an evaluation was made of the forward speed at landing contact as percent above the stalling speed, the weights of the airplanes were required for the determination of the stalling speed. This information, however, was not available and hence the weights were estimated on the following basis. The operational engineering section at Carswell Air Force Base indicated that the mean weight at landing for the end of a long mission was of the order of 210,000 to 220,000 pounds (220,000 pounds was used in the analysis herein for this group) and that the take-off weights of aircraft planning to practice landings was about 275,000 pounds. For this latter group of multiple landings, 270,000 pounds was taken as the weight for the first landing, and succeeding landings were assumed to be 4,000 to 6,000 pounds less than the previous one, depending on the time between landings. The lowest weight assumed for any landing was about 210,000 pounds and the total change in stalling speed for the range in weights used was about 12 miles per hour.

The airspeed at contact was determined as the sum of the measured horizontal speed (with respect to the ground) and the parallel component (in the direction of the runway) of wind velocity measured at the control tower.

DISCUSSION

Sinking Speed

The frequency distribution of sinking speed (fig. 1(a)) shows that the greatest number of landings (32 out of 144 or 22.2 percent) occurred in the range from 1.5 to 2.0 feet per second. The mean sinking speed for all 144 landings was 2.29 feet per second. The maximum sinking speed observed was 7.1 feet per second; the next lower value was 5.1 feet per second.

The probability curve of sinking speed for all landings (fig. 2(a)) indicates that a sinking speed of $5\frac{1}{2}$ feet per second will be equaled or exceeded once in about 100 landings; a sinking speed of 7 feet per second will probably be equaled or exceeded once in about 1,000 landings. For the transport airplanes (ref. 1), the sinking speeds that would be equaled or exceeded once in 100 and 1,000 landings were 3.5 feet per second and 4.3 feet per second, respectively.

Bank Angle

The frequency distribution of bank angles for the landings (fig. 1(b)) show that most of the landings were made at relatively small angles of bank; 70 percent of the landings were made at angles of bank of 1° or less. The mean bank angle was 0.77°, and no landing exceeded a bank angle of 3.6°. There was about equal distribution of bank angles to the right and left. The curve for the probability of equaling or exceeding given angles of bank for the 86 landings of the bomber for which this quantity was obtained (fig. 2(b)) indicates that an angle of bank of 3° will probably be equaled or exceeded once in about 100 landings; $4\frac{1}{2}^{\circ}$ will probably be equaled or exceeded once in about 1,000 landings. For the transport airplanes the comparable values of bank angle were 4.5° and 6.2°, respectively. The limitation of bank angle imposed by some part of the bomber airplane other than the landing gear contacting the ground first is about 11° (for the jet pods). It thus appears that the bank angles likely to be attained are substantially below that at which the jet pods will touch.

Rolling Velocity

The frequency distribution of rolling velocities indicates that they were divided about evenly for rolling either toward or away from the first wheel to touch (fig. 1(c)). However, the rolling velocities

averaged somewhat higher for rolling in the direction of first wheel
to touch, the mean being 0.65° per second; for rolling away from the
first wheel to touch, the mean was 0.46° per second. The maximum rolling
velocity in the direction of first wheel to touch was 2.1° per second
and away from the first wheel to touch was 1.4° per second. The prob-
ability curves of rolling velocity (fig. 2(c)) were computed by con-
sidering the group of rolling velocities in each direction as an entity.
Then the ordinates of the resulting curves for rolling toward and away
from the first wheel to touch were multiplied by 0.52 and 0.48, respec-
tively (relative percentages of occurrence of the two cases) to obtain
the final curves. (See fig. 2(c).)

The probability curves of rolling velocity indicate a greater
probability of equaling or exceeding a given value for the bomber
rolling in the direction of the first wheel to touch than for rolling
away. Out of 1,000 landings the rolling velocities likely to be equaled
or exceeded once are about 3° per second and 2° per second for rolling
toward or away, respectively, from the first wheel to touch; for the
transport landings, the corresponding values are 5° per second - the
same for either direction.

Airspeed at Contact

The frequency distribution of airspeeds at contact expressed as
percentage above the stalling speed (fig. 1(d)) indicates that the
greatest number of landings (34 out of 144 or 23.6 percent) occurred
in the range from 15 to 20 percent above the stall. The mean airspeed
at contact was 18.7 percent above the stall, and the maximum was about
40 percent above the stall.

The probability curve of airspeed at contact indicates that 1 out
of 100 landings will be made at a speed equal to or greater than 40 per-
cent above the stall; 1 out of 1,000 will equal or exceed 50 percent
above the stall. For the transport airplanes the corresponding values
of airspeed at contact were 50 percent above the stall for 1 out of
100 landings and 60 percent above the stall for 1 out of 1,000 landings.

CONCLUSIONS

Results of the analysis of the landing contact conditions of
144 landings of heavy bomber airplanes during routine daytime opera-
tions at Carswell Air Force Base have indicated the following:

1. The mean values of sinking speed, bank angle, rolling velocity (toward the first wheel to touch), and airspeed at contact were, respectively, 2.29 feet per second, 0.77°, 0.65° per second, and 18.7 percent above the stalling speed.

2. A sinking speed of about 7 feet per second, a bank angle of about $4\frac{1}{2}°$, a rolling velocity of about 3° per second (toward the first wheel to touch), or an airspeed at contact of about 50 percent above the stalling speed will probably be equaled or exceeded once in 1,000 landings.

Langley Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va., April 15, 1955.

<div align="center">REFERENCES</div>

1. Silsby, Norman S.: Statistical Measurements of Contact Conditions of 478 Transport-Airplane Landings During Routine Daytime Operations. NACA TN 3194, 1954.

2. Rind, Emanuel: A Photographic Method for Determining Vertical Velocities of Aircraft Immediately Prior to Landing. NACA TN 3050, 1954.

3. Kenney, John F.: Mathematics of Statistics. Pt. II. D. Van Nostrand Co., Inc., 1939, pp. 45-51.

TABLE I

GENERAL SPECIFICATION DATA FOR HEAVY BOMBER

Maximum gross weight (depending on model), lb . . . 357,000 to 410,000
Wing area, sq ft   4,772
Maximum wing loading, lb/sq ft   . . . . 74.7 to 85.8
Normal maximum permissible landing weight, lb 325,000
Nominal landing weight, lb   . . . . 210,000 to 270,000
Maximum lift coefficient (landing condition) 2.00

TABLE II

VALUES OF CONTACT CONDITIONS AND OTHER

PERTINENT DATA FOR LANDINGS

Date of landing	Time of landing	Wind direction	Wind velocity, mph	Maximum gust velocity, mph	Parallel wind component, mph (a)	Crosswind component, mph	Sinking speed, fps	Rolling velocity, deg/sec (b)	Bank angle, deg (c)	Forward ground speed, mph	Airspeed, mph
May 19	1245	NNW	7	--	6.5	2.7	2.1	-0.4	-0.2	121.7	128.2
May 19	1329	NNW	5	--	4.6	1.9	.8	-.2	.5	118.2	122.8
May 19	1407	NNW	5	--	4.6	1.9	1.6	-.2	-.8	110.9	115.5
May 19	1424	NNW	5	--	4.6	1.9	2.9	1.6	-.9	112.0	116.6
May 19	1429	NNW	5	--	4.6	1.9	.9	.3	-1.3	111.3	115.9
May 19	1445	NNW	5	--	4.6	1.9	1.6	----	----	114.1	118.7
May 19	1515	NNW	6	--	5.5	2.3	3.0	-.2	.7	119.6	125.1
May 19	1548	NNW	6	--	5.5	2.3	4.9	----	----	118.3	123.8
May 19	1619	NNE	8	--	7.4	3.1	1.4	.8	-.1	120.4	127.8
May 19	1624	NNE	8	--	7.4	3.1	.9	1.6	-.2	118.8	126.2
May 20	1125	E	10	--	0	10.0	1.9	----	----	120.9	120.9
May 20	1436	ENE	8	--	3.1	7.4	3.5	----	----	125.0	128.1
May 20	1445	ENE	8	--	3.1	7.4	1.9	-.2	-.6	131.0	134.1
May 20	1715	ENE	12	--	4.6	11.1	2.3	.4	.6	112.6	117.2
May 21	1004	SE	14	--	9.9	9.9	3.0	-.1	3.6	106.0	115.9
May 21	1142	SSE	16	--	14.8	6.1	1.3	.5	-1.2	111.4	126.2
May 21	1228	SSE	16	--	14.8	6.1	2.8	----	----	117.4	132.2
May 21	1300	SSE	14	25	12.9	5.4	2.6	-1.0	.9	123.0	135.9
May 21	1315	SSE	14	25	12.9	5.4	2.0	-.1	-1.9	113.5	126.4
May 21	1550	SSE	12	--	11.1	4.6	2.4	----	----	97.5	108.6
May 21	1622	SSE	15	--	13.9	5.7	1.2	----	----	115.0	128.9
May 21	1635	SSE	15	--	13.9	5.7	1.2	----	----	103.4	117.3
May 21	1703	SE	16	--	11.3	11.3	.9	.1	-1.4	105.7	117.0
May 21	1708	SE	16	--	11.3	11.3	2.9	----	----	100.8	112.1
May 21	1728	SE	16	--	11.3	11.3	2.6	----	----	105.9	117.2
May 21	1750	SE	16	--	11.3	11.3	2.1	----	----	100.1	111.4
May 21	1755	SE	16	--	11.3	11.3	1.7	----	----	102.4	113.7
May 21	1803	SE	12	--	8.5	8.5	1.3	.2	-.1	100.1	108.6
May 21	1807	SE	12	--	8.5	8.5	4.8	----	----	101.3	109.8
May 21	1815	SE	12	--	8.5	8.5	4.8	----	----	112.8	121.3

[a]Positive values indicate head wind.
[b]Positive values indicate roll toward first wheel to touch.
[c]Positive values indicate right bank.

TABLE II.- Continued

VALUES OF CONTACT CONDITIONS AND OTHER

PERTINENT DATA FOR LANDINGS

Date of landing	Time of landing	Wind direction	Wind velocity, mph	Maximum gust velocity, mph	Parallel wind component, mph (a)	Crosswind component, mph	Sinking speed, fps	Rolling velocity, deg/sec (b)	Bank angle, deg (c)	Forward ground speed, mph	Airspeed, mph
May 24	1515	SW	12	--	8.5	8.5	0.1	----	----	114.5	123.0
May 24	1618	S	8	--	8.0	0	.8	.3	.8	106.7	114.7
May 24	1620	S	8	--	8.0	0	2.4	-.1	-.3	118.2	126.2
May 24	1652	S	8	--	8.0	0	2.4	-.1	-1.1	115.8	123.0
May 24	1714	SSW	8	--	7.4	3.1	2.3	----	----	111.7	119.1
May 25	1008	NW	7	--	5.0	5.0	2.6	----	----	135.5	140.5
May 25	1035	NW	7	--	5.0	5.0	1.3	-.2	1.0	132.7	137.7
May 25	1327	NW	9	--	6.4	6.4	2.7	-.6	-.3	136.1	142.5
May 25	1527	SE	8	--	-5.7	5.7	1.5	.4	-.9	104.1	98.4
May 25	1545	SE	8	--	-5.7	5.7	3.2	.9	0	105.8	100.1
May 25	1620	SE	5	--	-3.5	3.5	1.8	----	----	114.1	110.6
May 25	1632	SE	5	--	-3.5	3.5	.8	.7	-1.0	110.6	107.1
May 25	1647	SE	5	--	-3.5	3.5	2.8	-.1	-.1	122.5	119.0
May 25	1657	SE	5	--	-3.5	3.5	2.5	----	----	114.4	110.9
May 26	1545	SSE	11	--	10.2	4.2	2.7	.1	-.1	97.7	107.9
May 27	0909	S	10	--	10.0	0	1.4	----	----	128.0	138.0
May 27	0945	S	10	--	10.0	0	3.8	----	----	120.1	130.1
May 27	1012	SSE	10	20	9.2	3.8	2.5	0	1.0	121.8	131.0
May 27	1233	SSE	12	22	11.1	4.6	1.9	----	----	107.8	118.9
May 27	1327	SSE	12	22	11.1	4.6	2.9	----	----	102.8	113.9
May 27	1355	SSE	12	22	11.1	4.6	1.1	----	----	91.2	102.3
May 27	1417	SSE	12	20	11.1	4.6	1.7	.4	1.6	112.2	123.3
May 27	1608	SSE	18	25	16.6	6.9	1.2	-.2	.9	105.0	121.6
May 27	1638	SSE	18	25	16.6	6.9	2.1	.2	-1.0	92.9	109.5
May 27	1645	SSE	18	25	16.6	6.9	1.8	----	----	96.0	112.6
May 27	1730	SSE	16	23	14.8	6.1	.7	.2	0	89.6	104.4
May 27	1748	SSE	16	23	14.8	6.1	1.1	----	----	110.4	125.2
May 27	1805	SSE	15	--	13.9	5.7	1.0	-.4	.4	97.2	111.1

[a]Positive values indicate head wind.

[b]Positive values indicate roll toward first wheel to touch.

[c]Positive values indicate right bank.

TABLE II.- Continued

VALUES OF CONTACT CONDITIONS AND OTHER

PERTINENT DATA FOR LANDINGS

Date of landing	Time of landing	Wind direction	Wind velocity, mph	Maximum gust velocity, mph	Parallel wind component, mph (a)	Crosswind component, mph	Sinking speed, fps	Rolling velocity, deg/sec (b)	Bank angle, deg (c)	Forward ground speed, mph	Airspeed, mph
May 28	1040	S	16	31	16.0	0	2.1	----	----	96.8	112.8
May 28	1055	S	16	31	16.0	0	2.4	-.2	.9	107.0	123.0
May 28	1255	WSW	14	--	5.4	12.9	4.1	2.1	1.6	104.8	110.2
May 28	1358	SSW	14	--	12.9	5.4	1.9	----	----	123.8	136.7
May 28	1500	SSW	14	--	12.9	5.4	3.3	----	----	130.0	142.9
May 28	1538	SSW	14	--	12.9	5.4	3.0	-.6	.4	112.6	125.5
May 28	1600	S	14	--	14.0	0	1.5	-.8	.3	98.5	112.5
May 28	1616	S	14	--	14.0	0	2.9	.5	-.4	103.3	117.3
May 28	1643	S	14	--	14.0	0	.1	----	----	99.1	113.1
June 1	1541	SE	10	--	7.1	7.1	5.1	----	----	109.2	116.3
June 1	1548	SE	10	--	7.1	7.1	1.8	-.7	.8	105.7	112.8
June 2	0853	S	28	38	28.0	0	1.6	----	----	105.4	133.4
June 2	0920	S	25	--	25.0	0	4.4	----	----	101.4	126.4
June 2	1319	SW	15	--	10.6	10.6	2.6	-1.4	.7	121.2	131.8
June 2	1404	SW	12	--	8.5	8.5	3.1	----	----	114.7	123.2
June 2	1436	SW	12	--	8.5	8.5	2.2	----	----	112.9	121.4
June 2	1442	SW	12	--	8.5	8.5	2.2	-.2	.4	117.4	125.9
June 3	0928	NNW	14	22	12.9	5.4	3.8	-.3	1.1	105.8	118.7
June 3	1334	NNW	20	26	18.5	7.7	2.1	-.2	-.8	108.3	126.8
June 3	1405	NNW	20	26	18.5	7.7	1.6	.2	-.9	102.7	121.2
June 3	1432	NNW	20	26	18.5	7.7	1.6	----	----	105.1	123.6
June 3	1511	NNW	20	28	18.5	7.7	3.5	----	----	117.8	136.3
June 3	1544	NNW	20	28	18.5	7.7	.6	.6	2.4	122.1	140.6
June 3	1701	NNW	12	--	11.1	4.6	1.1	----	----	117.5	128.6
June 3	1703	NNW	12	--	11.1	4.6	1.6	1.5	-2.8	100.7	111.8
June 3	1735	NNW	12	--	11.1	4.6	1.9	0	0	109.7	120.8

[a]Positive values indicate head wind.
[b]Positive values indicate roll toward first wheel to touch.
[c]Positive values indicate right bank.

TABLE II.- Continued

VALUES OF CONTACT CONDITIONS AND OTHER

PERTINENT DATA FOR LANDINGS

Date of landing	Time of landing	Wind direction	Wind velocity, mph	Maximum gust velocity, mph	Parallel wind component, mph (a)	Crosswind component, mph	Sinking speed, fps	Rolling velocity, deg/sec (b)	Bank angle, deg (c)	Forward ground speed, mph	Airspeed, mph
June 4	0858	E	8	--	0	8.0	2.0	0.4	0	137.0	137.0
June 4	0924	E	8	--	0	8.0	1.1	-.6	.4	142.5	142.5
June 4	1029	E	8	--	0	8.0	2.0	1.7	.1	102.5	102.5
June 4	1117	---	Calm	--	0	0	2.5	----	----	119.0	119.0
June 4	1124	---	Calm	--	0	0	3.2	.9	1.5	111.2	111.2
June 4	1141	---	Calm	--	0	0	4.2	-.7	-.5	118.1	118.1
June 4	1154	---	Calm	--	0	0	1.5	-.5	1.8	115.6	115.6
June 4	1208	SE	7	--	5.0	5.0	1.6	-1.2	.9	119.0	124.0
June 4	1322	SE	8	--	5.7	5.7	3.1	1.4	-.1	118.3	124.0
June 4	1413	E	6	--	0	6.0	3.8	.5	.6	118.1	118.1
June 4	1432	E	6	--	0	6.0	2.4	----	----	121.1	121.1
June 4	1458	E	6	--	0	6.0	3.8	----	----	113.8	113.8
June 4	1521	E	6	--	0	6.0	1.9	-.7	.3	124.6	124.6
June 4	1553	E	6	--	0	6.0	2.4	-1.2	.7	107.2	107.2
June 4	1603	ESE	10	--	-3.8	9.2	1.7	.3	.6	119.5	115.7
June 4	1605	ESE	10	--	-3.8	9.2	2.3	-.2	.5	135.6	131.8
June 4	1618	ESE	10	--	-3.8	9.2	2.3	----	----	113.0	109.2
June 4	1622	ESE	10	--	-3.8	9.2	2.0	-.5	0	121.9	118.1
June 4	1630	ESE	10	--	-3.8	9.2	3.5	.5	-.2	113.0	109.2
June 4	1654	ESE	10	--	-3.8	9.2	2.9	1.2	-1.3	126.6	122.8
June 4	1717	ESE	10	--	-3.8	9.2	2.4	-.1	.6	126.4	122.6
June 4	1719	ESE	10	--	-3.8	9.2	2.1	.1	-.1	124.4	120.6
June 4	1730	ESE	10	--	-3.8	9.2	2.7	-.9	-.6	126.9	123.1
June 4	1738	ESE	10	--	-3.8	9.2	2.0	.1	-.1	121.6	117.8
June 4	1759	ESE	10	--	-3.8	9.2	2.8	-.4	.2	121.3	117.5
June 7	1412	SSE	12	--	11.1	4.6	2.8	----	----	117.8	128.9
June 7	1437	SSE	12	--	11.1	4.6	1.6	.5	1.1	105.4	116.5
June 7	1510	SSE	12	--	11.1	4.6	1.9	----	----	111.5	122.6
June 7	1550	SSE	12	--	11.1	4.6	1.9	----	----	119.8	130.9
June 7	1604	SSE	12	--	11.1	4.6	1.8	-.1	-.1	99.0	110.1
June 7	1650	SSE	12	25	11.1	4.6	1.5	-.9	-.8	105.0	116.1
June 7	1710	SSE	18	28	16.6	6.9	1.7	1.0	1.3	92.3	108.9
June 7	1729	SSE	18	28	16.6	6.9	.6	----	----	99.7	116.3

aPositive values indicate head wind.

bPositive values indicate roll toward first wheel to touch.

cPositive values indicate right bank.

TABLE II.- Concluded

VALUES OF CONTACT CONDITIONS AND OTHER

PERTINENT DATA FOR LANDINGS

Date of landing	Time of landing	Wind direction	Wind velocity, mph	Maximum gust velocity, mph	Parallel wind component, mph (a)	Crosswind component, mph	Sinking speed, fps	Rolling velocity, deg/sec (b)	Bank angle, deg (c)	Forward ground speed, mph	Airspeed, mph
June 8	0941	S	14	25	14.0	5.4	1.2	0.5	-0.3	106.1	120.1
June 8	1000	S	20	28	20.0	0	3.2	1.0	.1	99.0	119.0
June 8	1150	S	16	30	16.0	0	2.8	.6	-.2	98.9	114.9
June 8	1202	S	14	30	14.0	0	4.9	-1.2	.9	96.0	110.0
June 8	1205	S	14	30	14.0	0	1.6	.1	.6	101.0	115.0
June 8	1220	S	14	30	14.0	0	2.8	----	----	94.3	108.3
June 8	1315	S	15	30	15.0	0	3.2	----	----	105.8	120.8
June 8	1348	S	15	30	15.0	0	1.0	----	----	99.6	114.6
June 8	1428	S	10	25	10.0	0	2.1	-.2	1.4	107.5	117.5
June 8	1530	SSE	10	28	9.2	3.8	.9	.1	1.7	109.6	118.8
June 8	1641	SSE	16	--	14.8	6.1	2.1	-.2	0	103.2	118.0
June 9	0923	SSE	24	32	22.2	9.2	3.7	----	----	92.4	114.6
June 9	1230	SSE	22	28	20.4	8.4	2.7	1.1	2.0	98.4	118.8
June 9	1436	SSE	20	32	18.5	7.7	4.0	.2	-1.1	107.8	126.3
June 9	1440	SSE	20	32	18.5	7.7	1.8	----	----	100.5	119.0
June 9	1505	SSE	20	34	18.5	7.7	1.9	----	----	100.4	118.9
June 9	1527	SSE	20	34	18.5	7.7	2.4	----	----	99.6	118.1
June 9	1535	SSE	20	34	18.5	7.7	2.6	----	----	117.8	136.3
June 9	1552	SSE	20	34	18.5	7.7	7.1	----	----	95.5	114.0
June 9	1617	SSE	18	28	16.6	6.9	1.9	----	----	114.2	130.8
June 9	1657	SSE	18	28	16.6	6.9	3.3	-.6	2.6	98.9	115.5
June 9	1705	SSE	20	--	18.5	7.7	1.3	1.0	-.6	104.8	123.3
June 9	1715	SSE	20	--	18.5	7.7	2.3	----	----	91.4	109.9
June 9	1741	SSE	20	--	18.5	7.7	2.3	----	----	111.8	130.3
June 11	1203	SSE	12	22	11.1	4.6	2.6	.2	-1.1	103.7	114.8
June 11	1210	SSE	12	22	11.1	4.6	3.8	1.7	.2	118.8	129.9
June 11	1433	SSE	12	20	11.1	4.6	1.6	.6	.3	102.9	114.0

[a]Positive values indicate head wind.
[b]Positive values indicate roll toward first wheel to touch.
[c]Positive values indicate right bank.

TABLE III

VALUES OF STATISTICAL PARAMETERS FOR LANDING-CONTACT CONDITIONS

(a) Sinking speed

Category	Number of Landings	Maximum sinking speed, ft/sec	Mean sinking speed, ft/sec	Standard deviation, σ, ft/sec	Coefficient of skewness, α_3
All bombers	144	7.1	2.29	1.08	0.90

(b) Bank angle

Category	Number of landings	Maximum bank angle, deg	Mean bank angle, deg	Standard deviation, σ, deg	Coefficient of skewness, α_3
All bombers	86	3.6	0.77	0.68	1.53

(c) Rolling velocity

Category	Number of landings	Maximum rolling velocity, deg/sec	Mean rolling velocity, deg/sec	Standard deviation, σ, deg/sec	Coefficient of skewness, α_3
Rolling toward first wheel to touch	45	2.1	0.65	0.53	0.96
Rolling away from first wheel to touch	41	1.4	.46	.37	.92

(d) Airspeed at contact

| Category	Number of landings	Maximum contact airspeed, percent above stall	Mean contact airspeed, percent above stall	Standard deviation, σ, percent above stall	Coefficient of skewness, α_3
All bombers	144	41	18.7	8.58	0.46
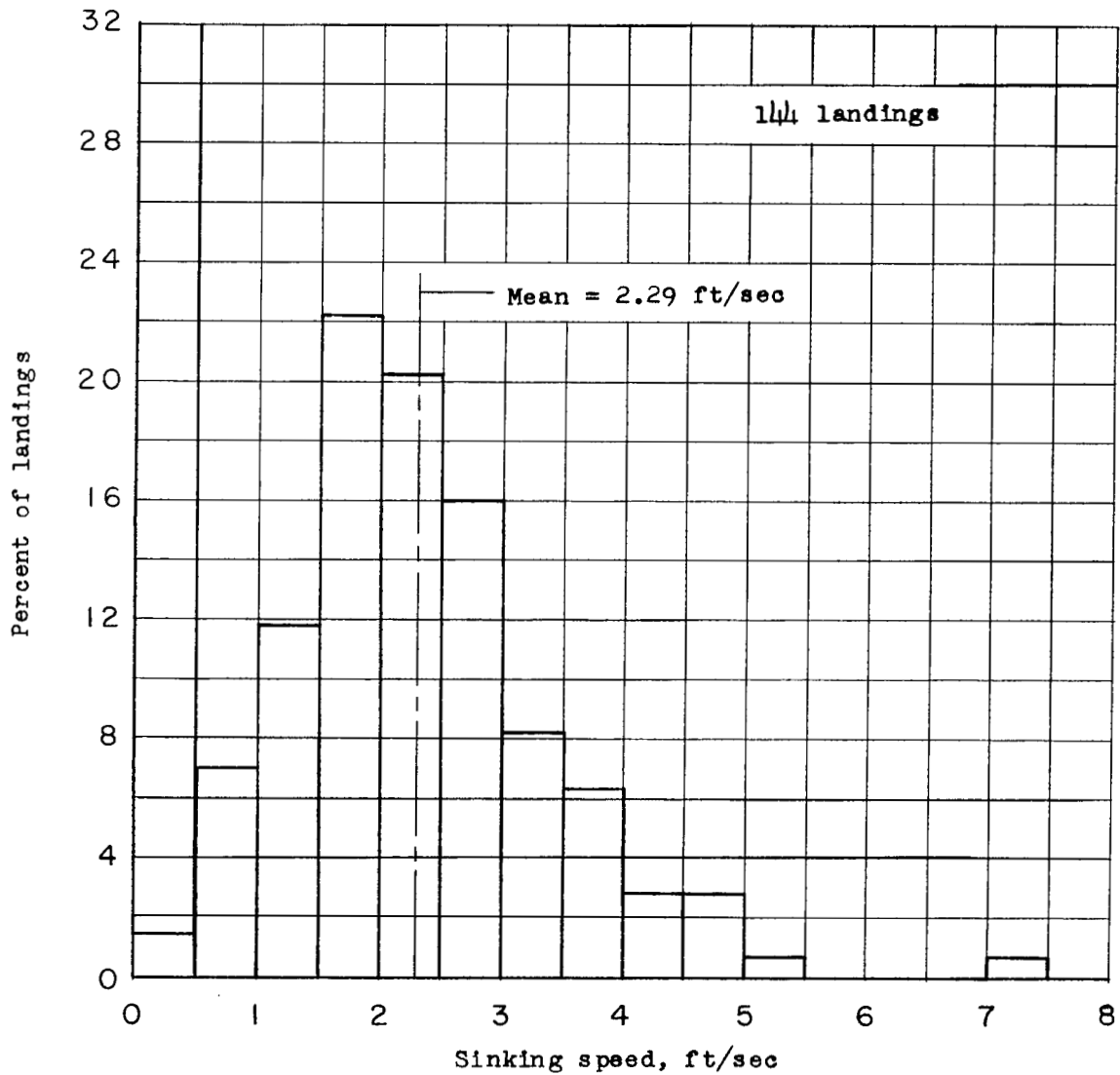
(a) Sinking speed.

Figure 1.- Frequency distributions of landing-contact conditions of a
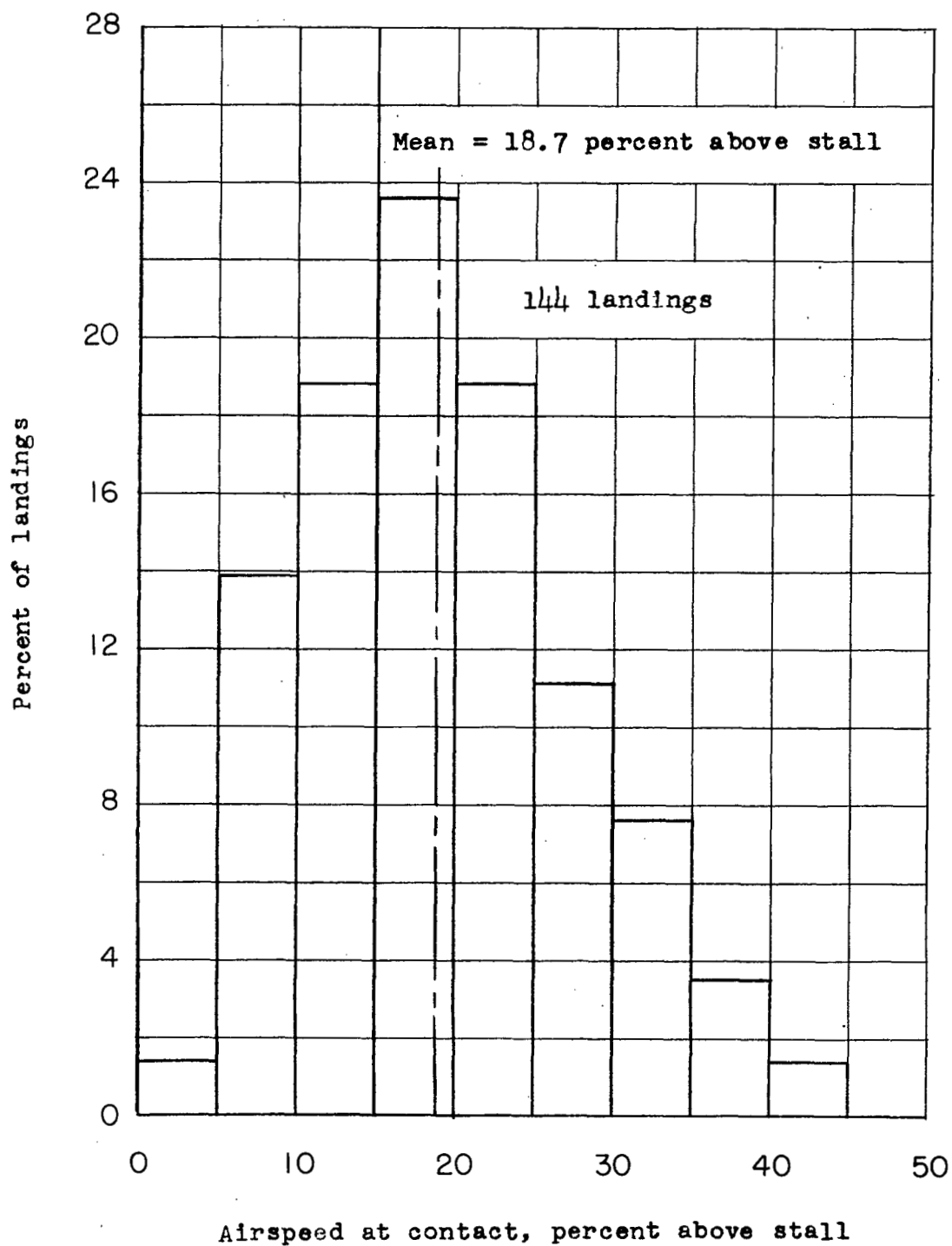heavy bomber during daytime operational landings.
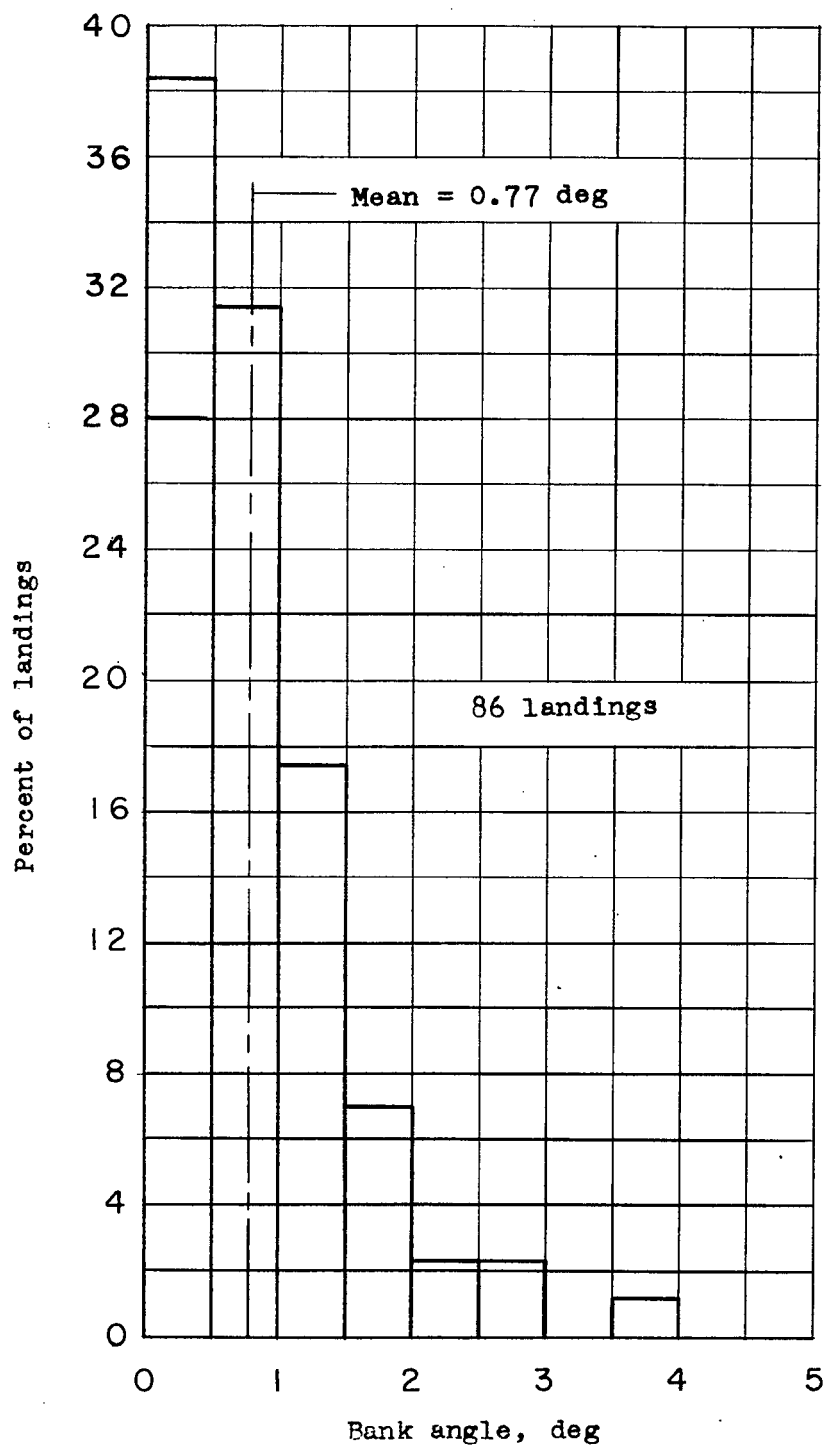
(b) Bank angle.
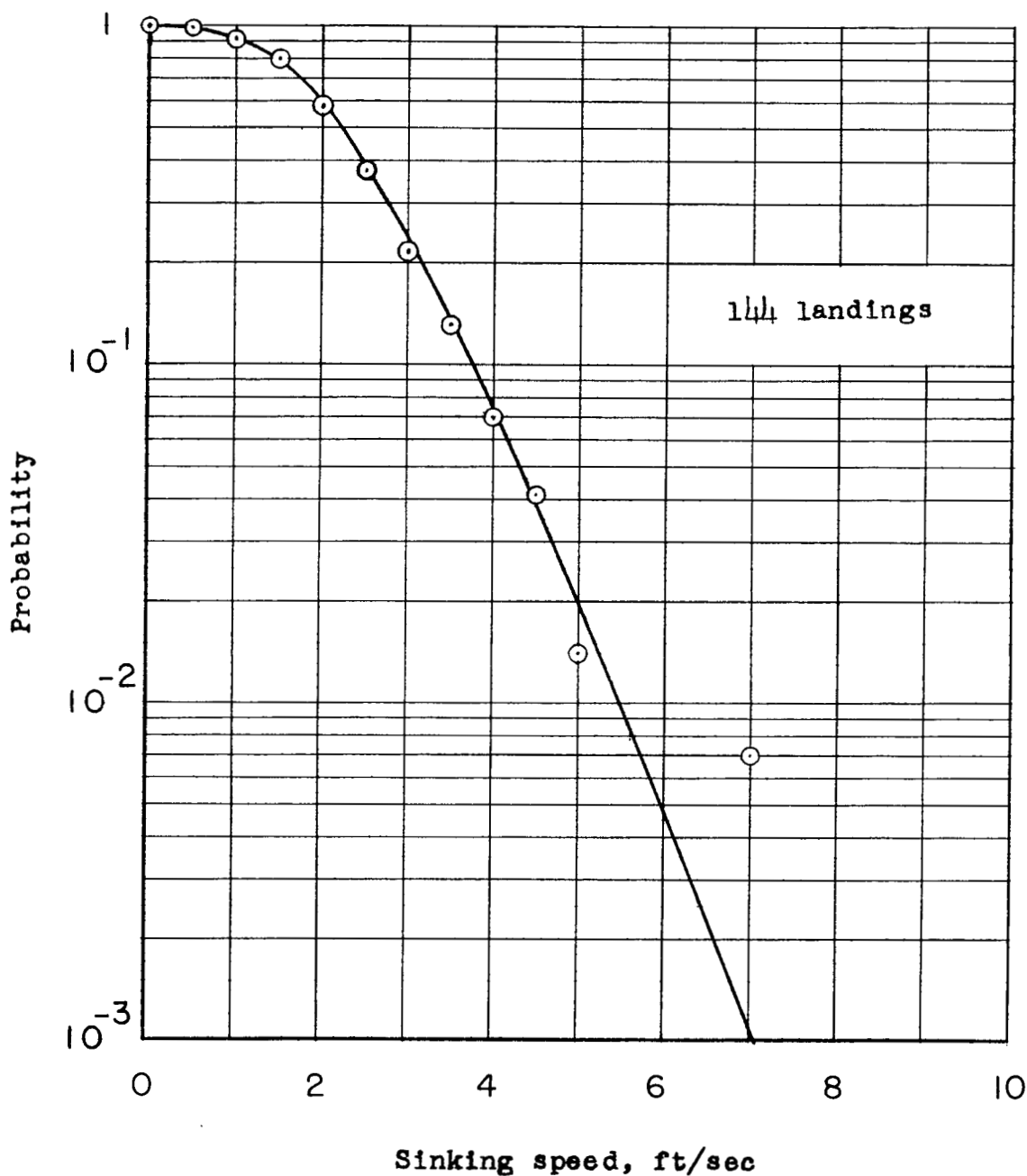
Figure 1.- Continued.
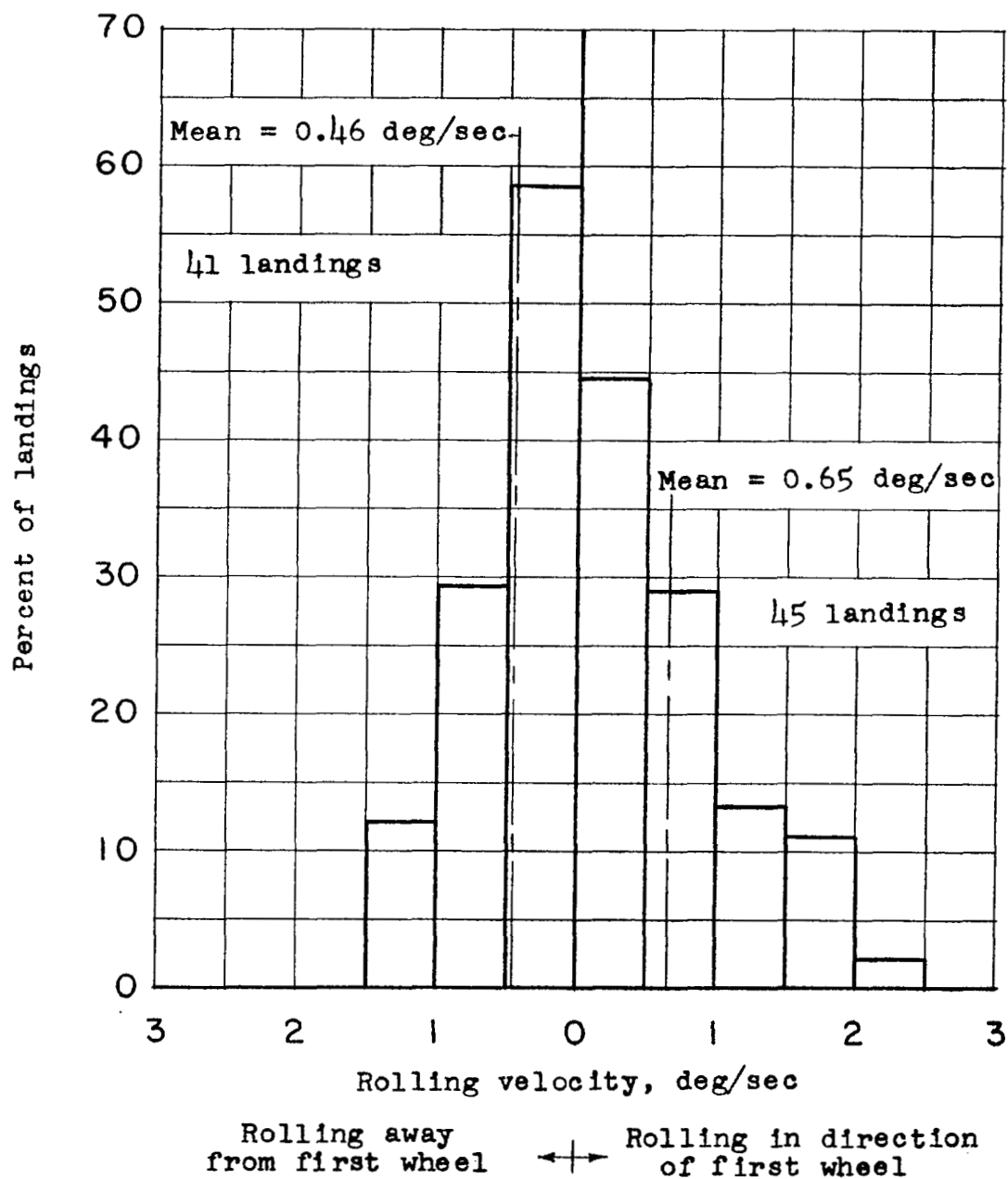
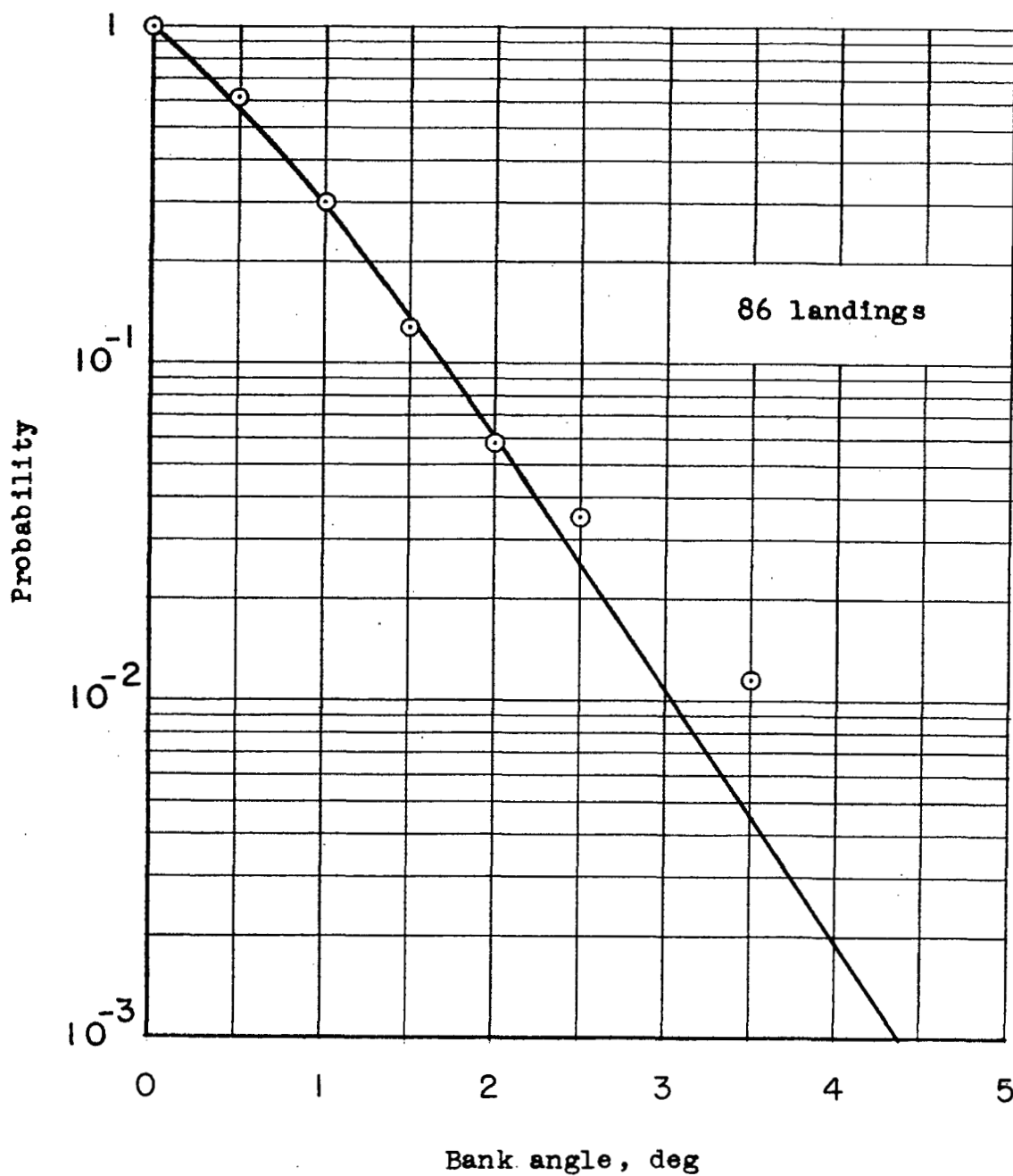(c) Rolling velocity.

Figure 1.- Continued.
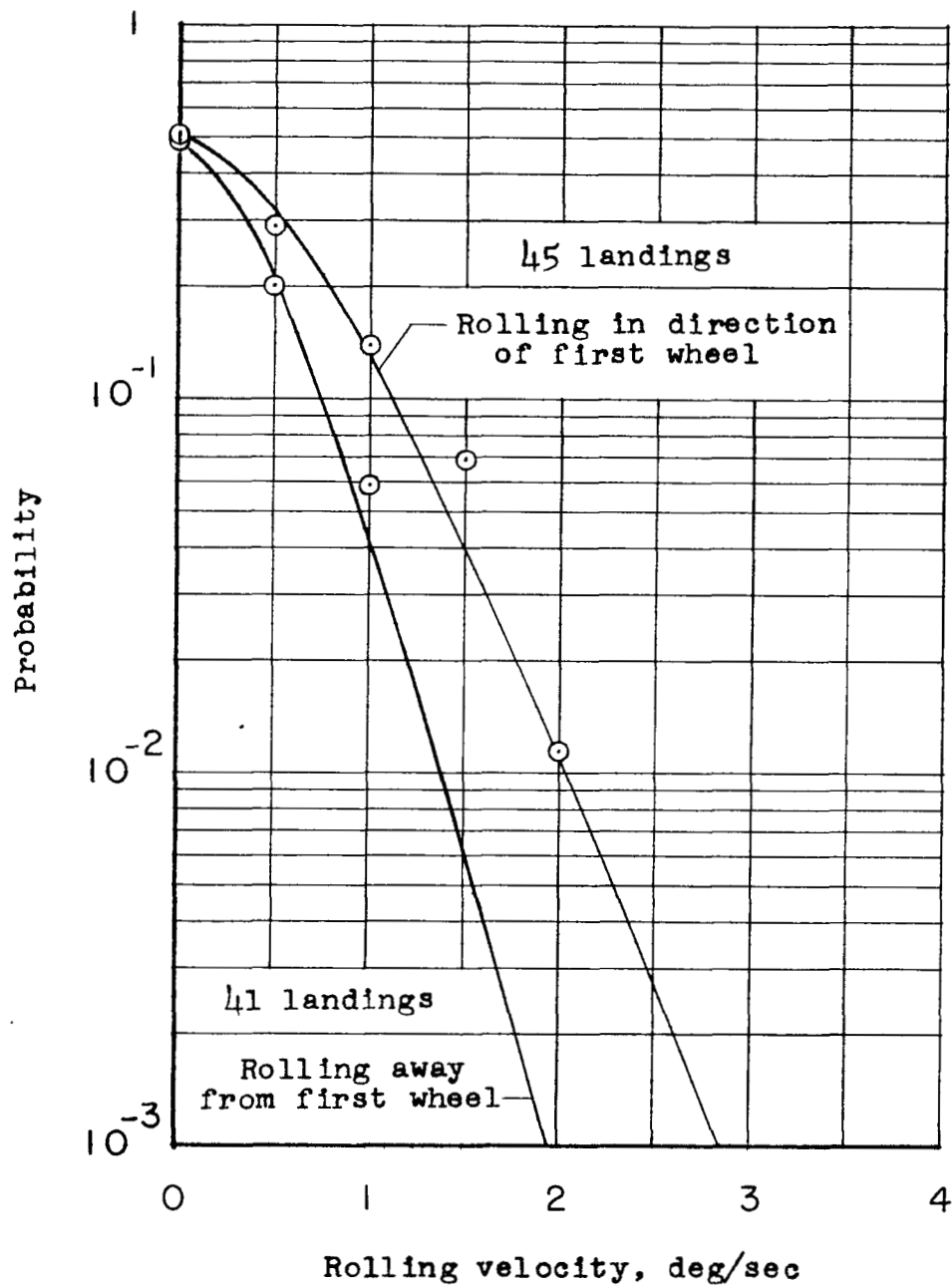
(d) Airspeed at contact.

Figure 1.- Concluded.

(a) Sinking speed.

Figure 2.- Probability curves of landing-contact conditions of a heavy bomber airplane during daytime operational landings.
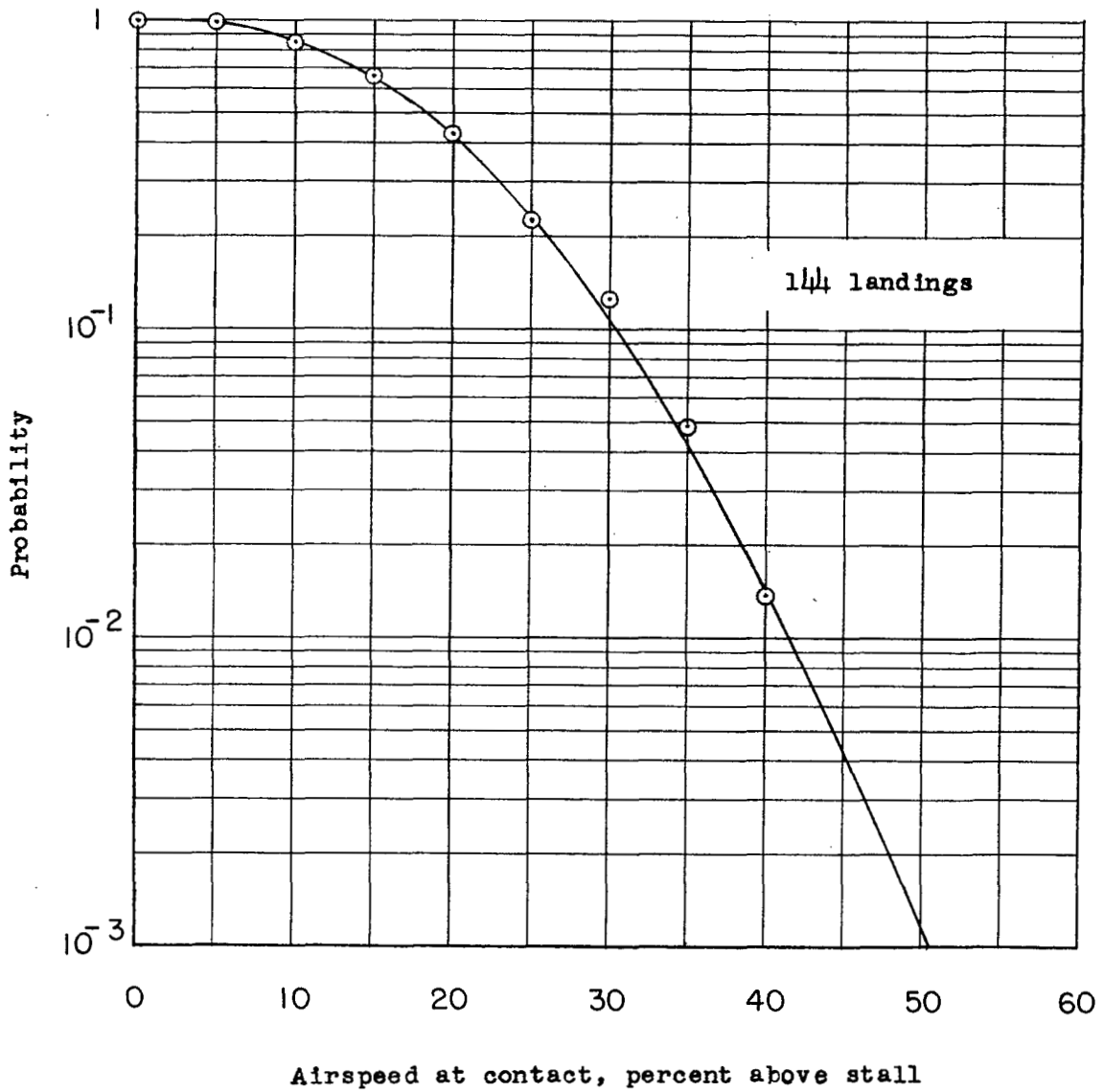
Bank angle, deg

(b) Bank angle.

Figure 2.- Continued.

(c) Rolling velocity.

Figure 2.- Continued.

Airspeed at contact, percent above stall

(d) Airspeed at contact.

Figure 2.- Concluded.